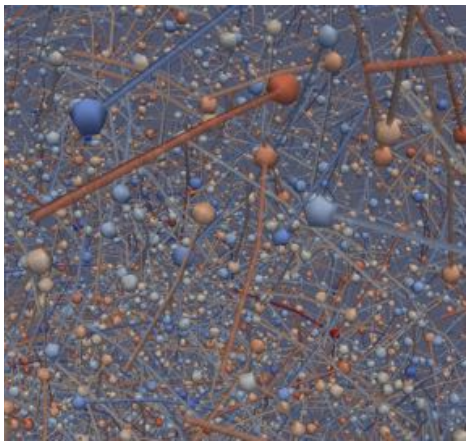
Visualization with Paraview within the UITS-RT Advanced Visualization Lab

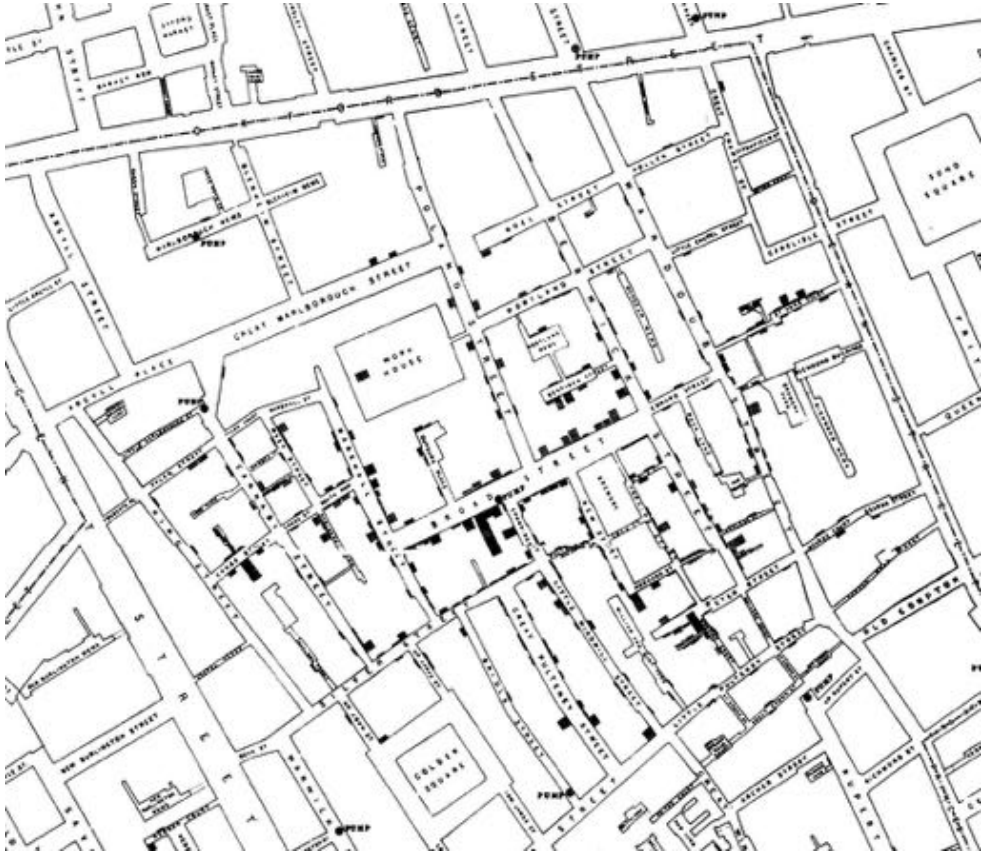
(for the Research Technologies workshop at Indiana University)



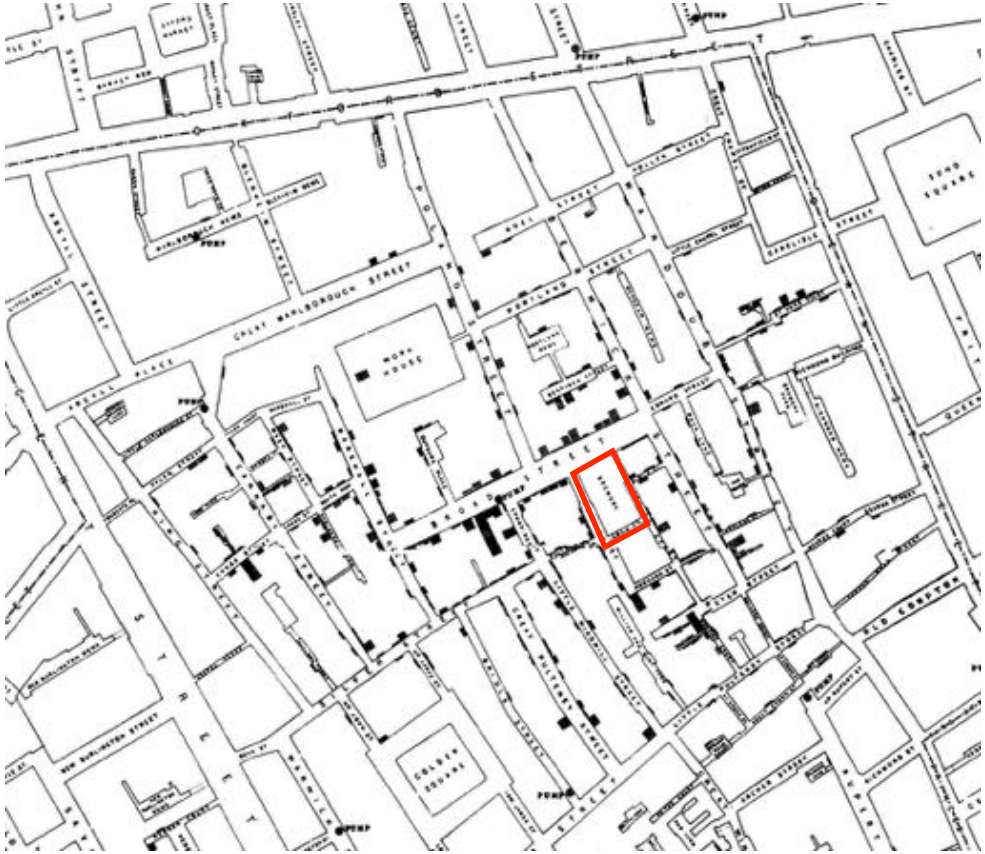
Bill Sherman
Advanced Visualization Lab
Indiana University

March 6, 2018

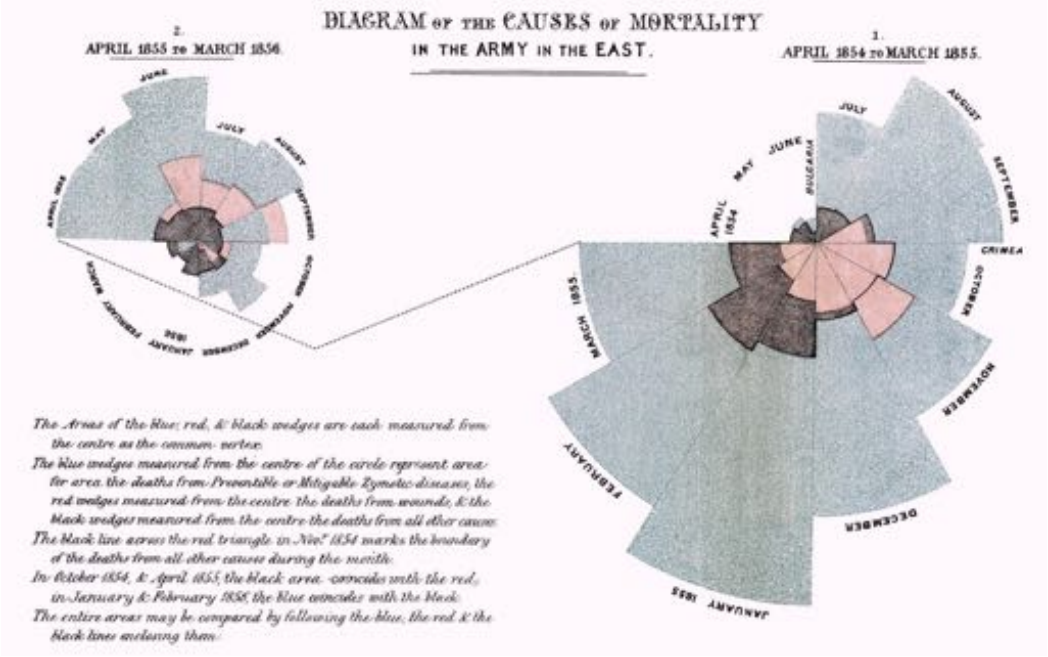
Visualisation is not new…



John Snow - cases of cholera in London (1663)

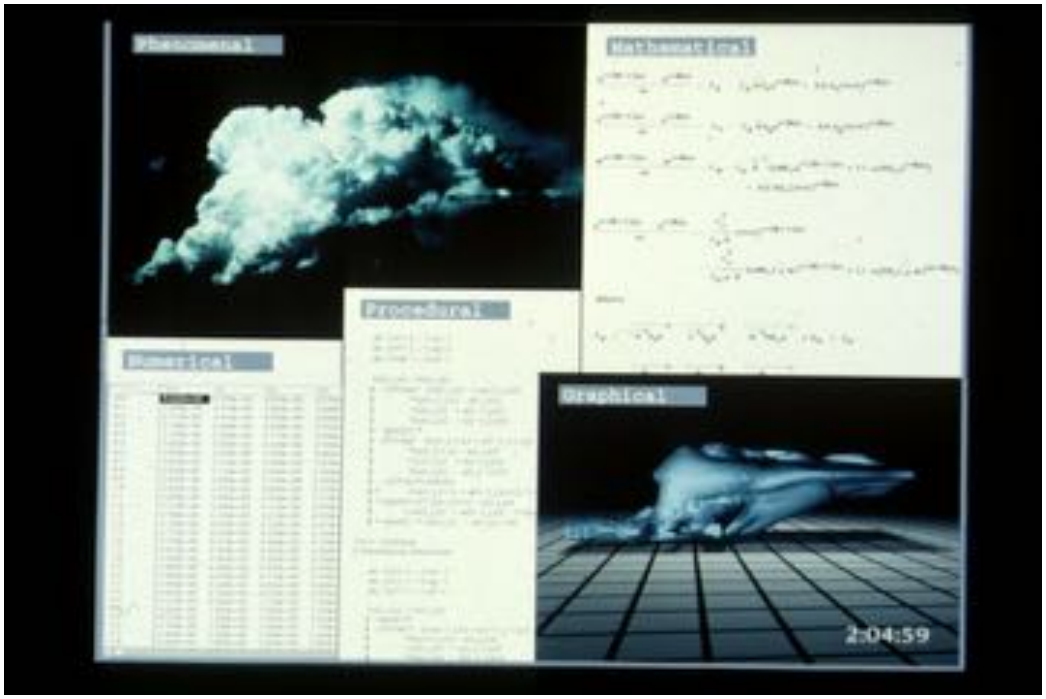


John Snow - cases of cholera in London (1663)



Florence Nightingale (1820-1910)
coxcomb chart monthly deaths from battle and other causes

The Visualization Process

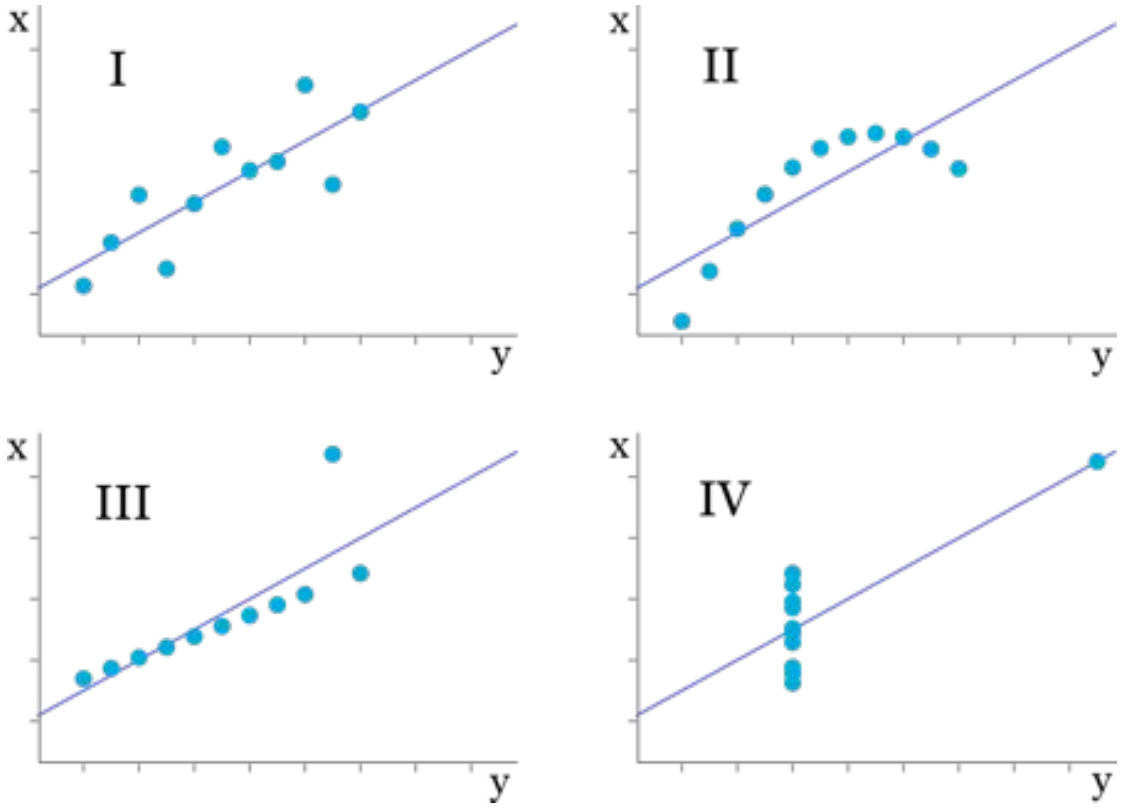


I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.80

n = 11

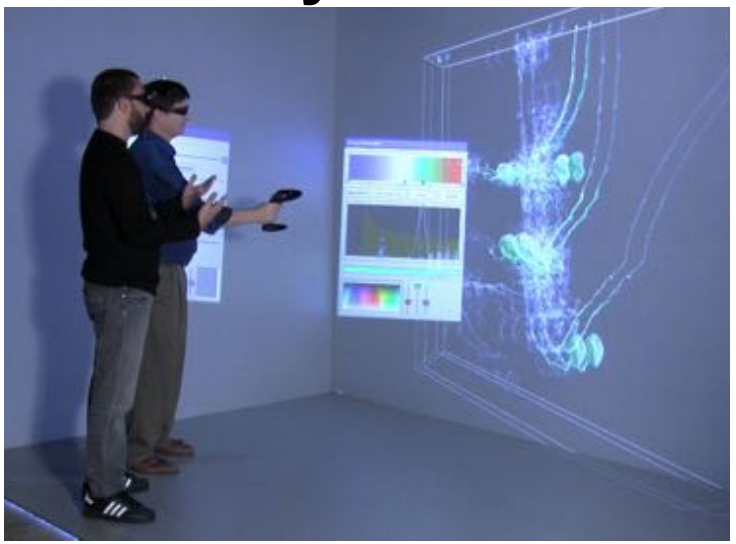
mean x = 9.0 variance x = 11.0 correlation x & y = 0.816

mean y = 7.5 variance y = 4.12 regression line: y = 3+0.5x


x
I
y
x
II
y
x
III
y
x
IV
y

Visualization dichotomy

- Batch vs. Interactive
- Interactive:
  - Explorative
  - Immediate feedback
  - Performance constraints
- Batch:
  - Pre-determined
  - Big-data / big-processing
  - HPC-ready



vs.

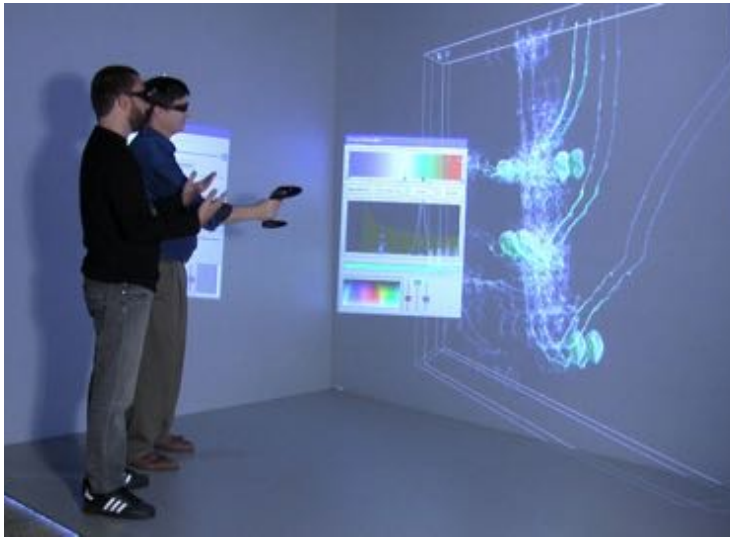
```
bigred2% qsub render-data.pbs
```

~~Visualization dichotomy~~
Visualization process

- ~~Batch vs. Interactive~~
- Interactive → Batch

- Interactive:
  - Explore
  - Reduced data

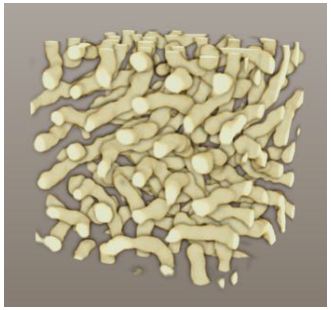
- Batch:
  - Guided by exploration
  - Full data / high-res



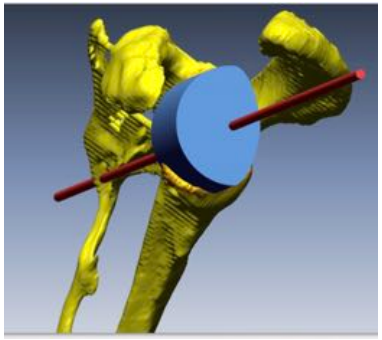
then

```
bigred2% qsub render-data.pbs
```

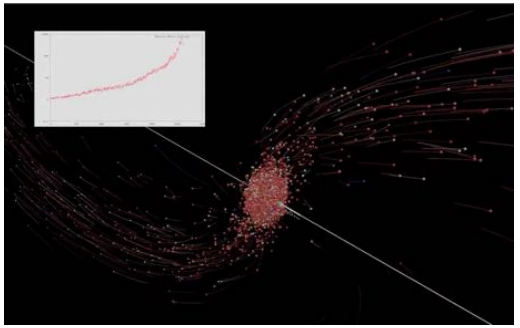
AVL Visualizations



- Reproduction of Clarinet Mouthpiece
- Patient-Specific Glenoid Surgical Guide

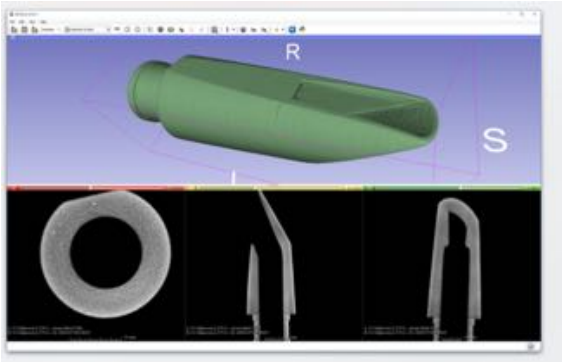


- Condensed Matter Astrophysics (Nuclear Pasta)
- Measuring Atmospheric Aerosols
- Dental Filling Material Analysis
- Globular Cluster Evolution
- Mouse Brain Neural Pathways



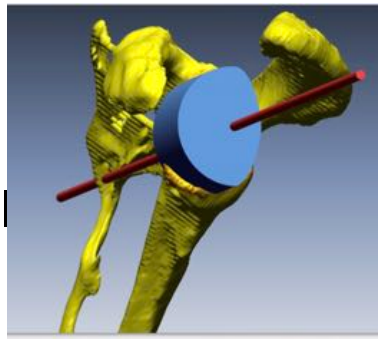
- These and other projects can be found at:
  - **https://showcase.avl.iu.edu**

AVL Visualizations



- **Reproduction of Clarinet Mouthpiece**
- For: Charles Davis, Informatics, IU
- Task: Capture (for reproduction) one of a kind hand-tooled clarinet mouthpiece
- Tools:
  - Slicer for Segmentation and Mesh Generation
  - Geomagic Design X for Mesh healing and smoothing
  - 3D Printing at Herron Think-It-Make-It Lab

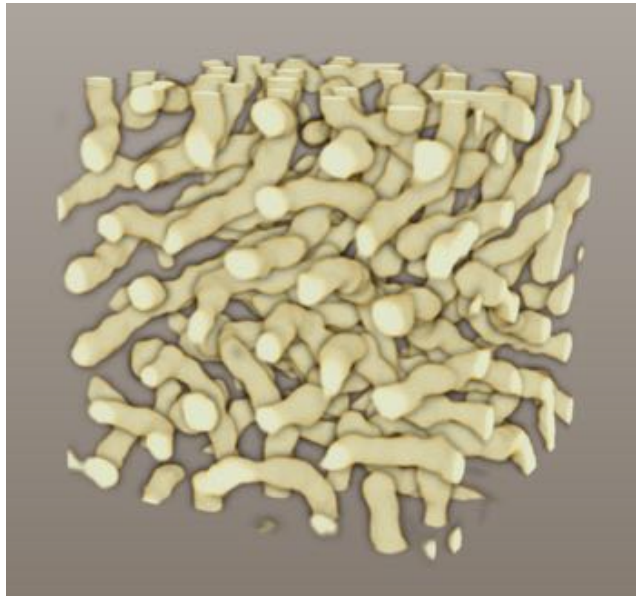
AVL Visualizations



- **Patient-Specific Glenoid Surgical Guide**
- For: Dr. Kenny Unruh, IU / Indiana Hand & Shoulder Cl
- Task: Produce custom guide for each operation
- Tools:
  - Slicer for 3D Mesh Generation
  - Maya for alignment
  - Geomagic Design X for Mesh healing
  - Rhino 3D for Boolean Operations
  - 3D Printing on Makerbot

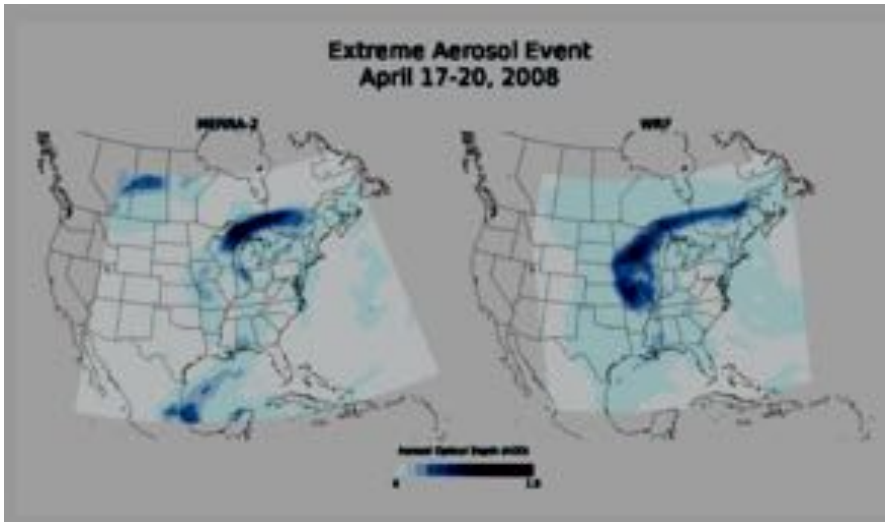
AVL Visualizations

- **Condensed Matter Astrophysics (Nuclear Pasta)**
- For: Charles Horowitz, Cyclotron/Physics
- Task: Produce analysis and videos for public
- Tools:
  - ParaView



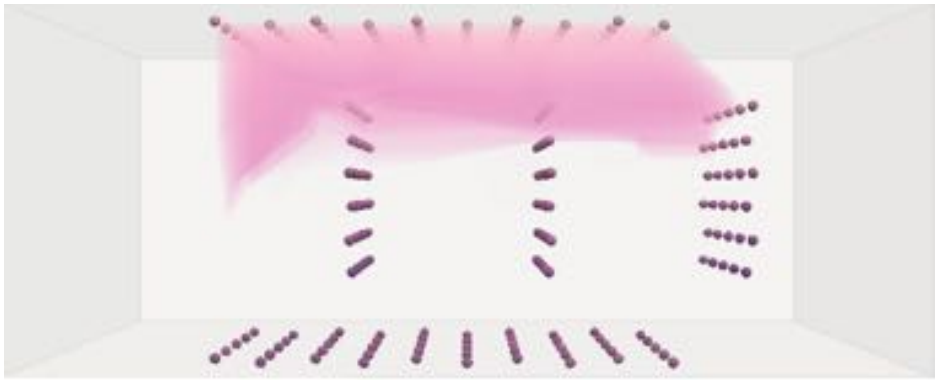
AVL Visualizations

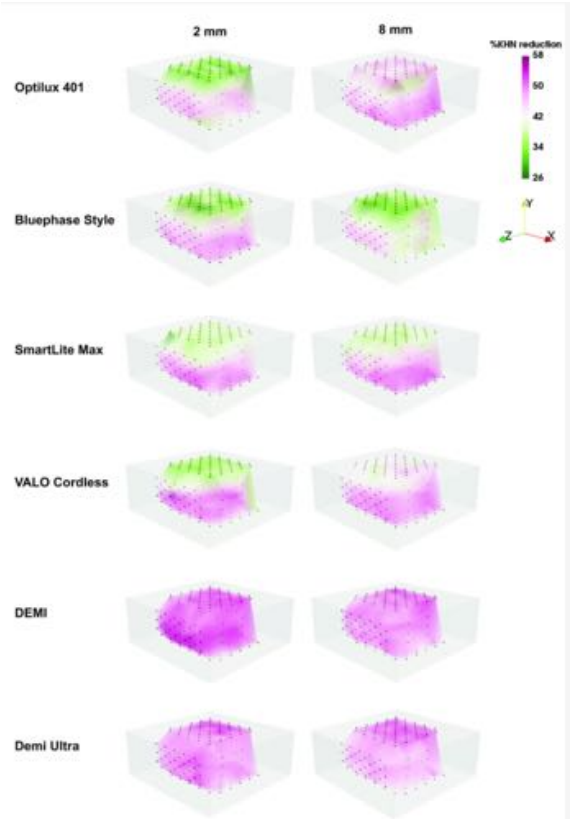
- **Measuring Atmospheric Aerosols**
- For: Sara Pryor
- Task: Produce analysis and videos for public
- Tools:
  - IDV (Integrated Data View, NCAR)
  - Matlab (by researcher)



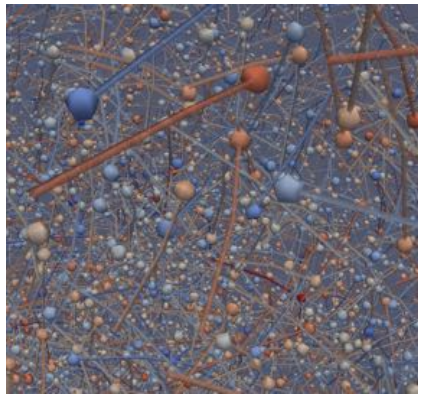
AVL Visualizations

- **Dental Filling Material Analysis**
- For: Afnan Al-Zain, IU School of Dentistry
- Task: Produce analysis and videos for public
- Tools:
  - ParaView
  - Excel (data prep)

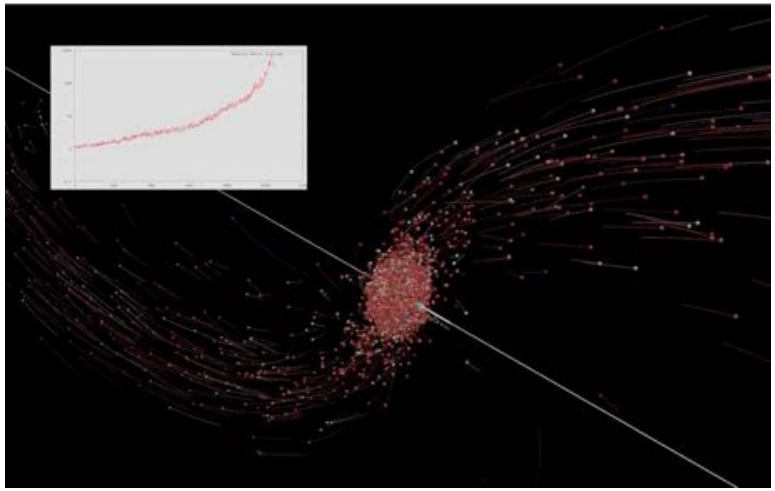




AVL Visualizations

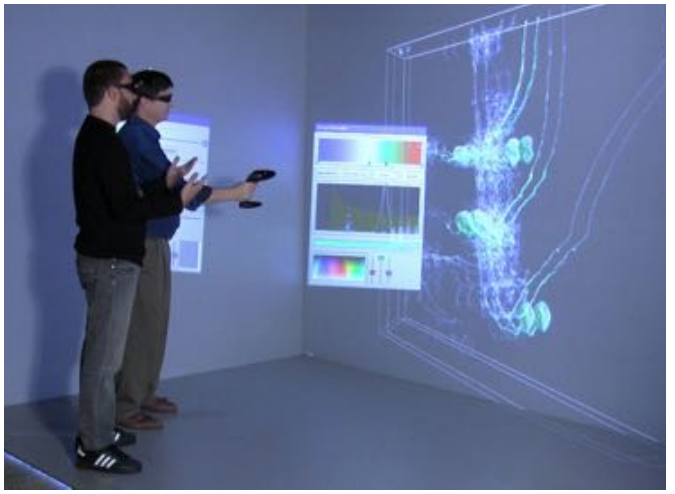


- **Globular Cluster Evolution**
- For: Enrico Vesperini
- Task: Produce analysis and videos for public
- Tools:
  - ParaView
  - (data prep)



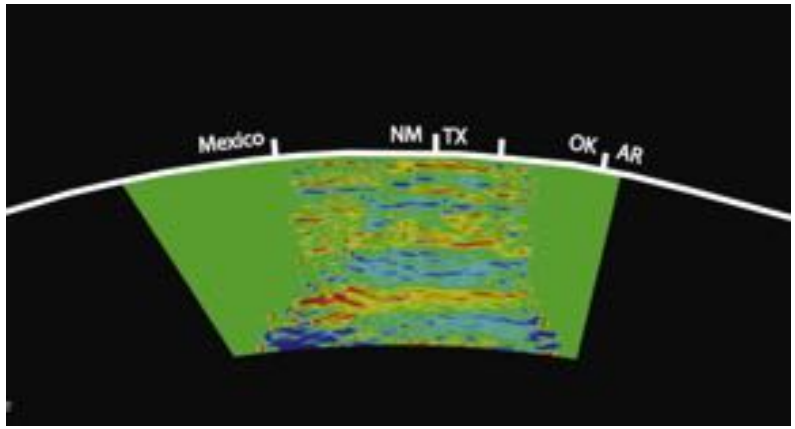
AVL Visualizations

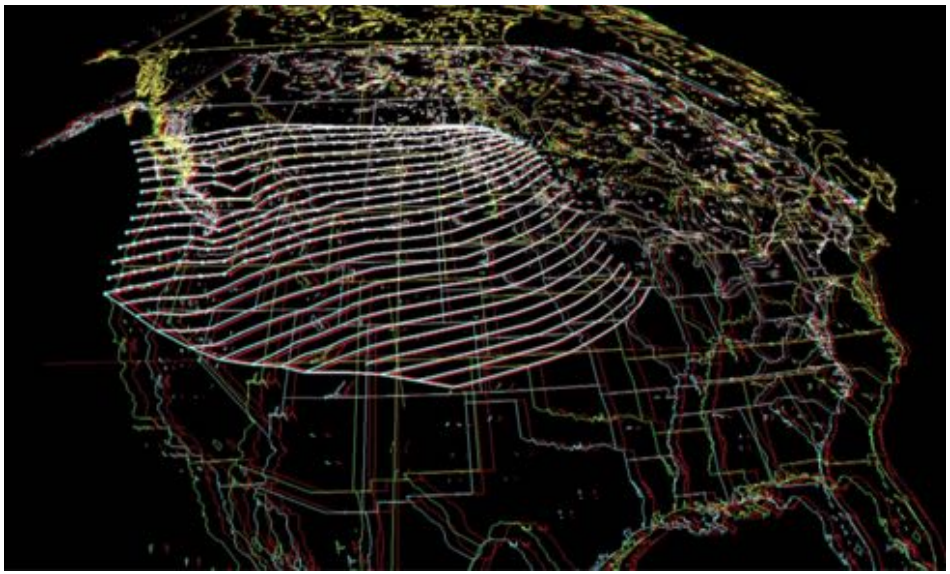
- **Mouse Brain Neural Pathways**
- For: Gavriil Tsechpenakis
- Task: Produce immersive analysis tools
- Tools:
  - Toirt Samhlaigh (Immersive Volume Vis tool)
  - IUPUI Virtual Reality Theater



AVL Visualization Help

- **Tectonic Plate Simulations**
- With: Gary Pavlis
- Task: Help provide ParaView and display support
- Tools:
  - ParaView





AVL Tool Shelf

- ParaView – General Purpose Sci-Vis
- VTK – Programmable Sci-Vis
- VMD – Molecular Visualization
- 3D Slicer – Volume Visualization
- IDV – Atmospheric Data
- Matlab – General data manipulation
- Geomagic Design X – Geometric analysis and cleaning
- Rhino 3D – Geometric manipulation, etc.
- Maya – Polygonal manipulation and animation
- Toirt Samhlaigh – Immersive Volume Visualization
- …

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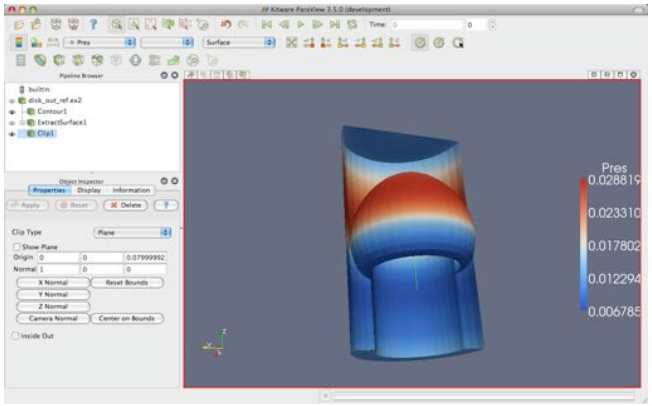
- …

ParaView & VTK

- General Purpose visualization tools from Kitware
- **VTK**:
  - Program your own tool with standard techniques
  - Can be scripted
    - Python, TCL, Java
  - Can be integrated into web notebooks
- **ParaView**:
  - Typical User Interface
  - Can be integrated into Web interfaces
  - Parallelizable
  - Uses the VTK library
  - Can be scripted
    - Python
  - MPI & CUDA available
    - Mostly CPU-based (for now)

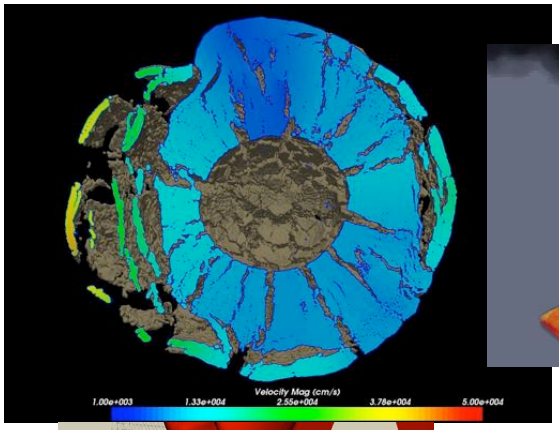


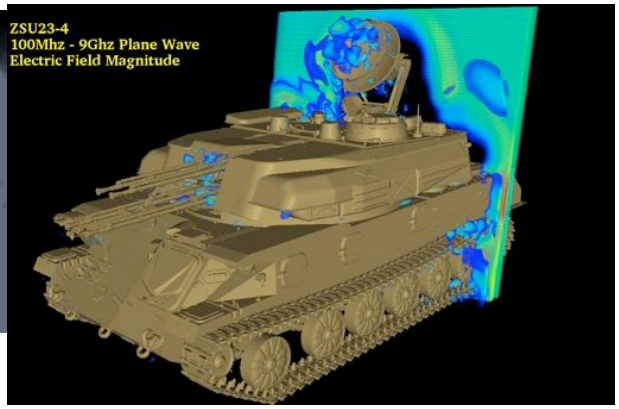
What is ParaView?

- An open-source, scalable, multi-platform visualization application.
- Support for distributed computation models to process large data sets.
- An open, flexible, and intuitive user interface.
- An extensible, modular architecture based on open standards.
- A flexible BSD-2 license.
- Commercial maintenance and support.

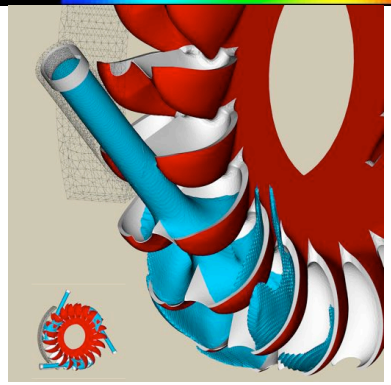
What Can ParaView Do?

- Interactive Desktop Exploration
- Parallel computation using HPC systems
- Batch Big-Iron (HPC) rendering
- Interactive & Immersive Interfaces
  - AVL large format displays
  - Consumer-grade HMD displays
- Customizable
  - C++ extensions
  - Python scripting
  - Web interface

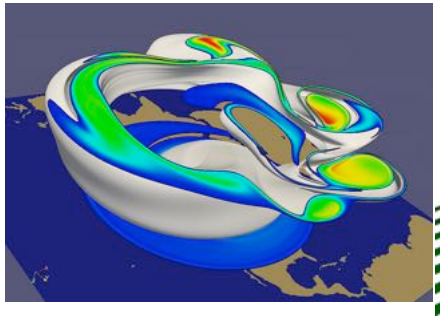


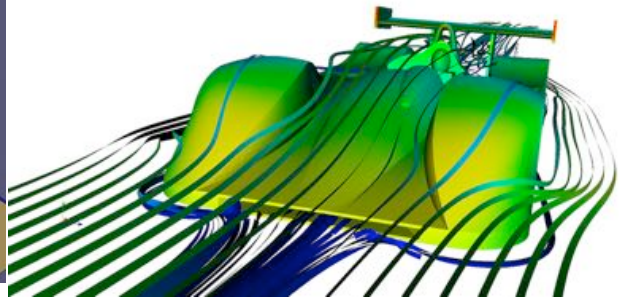


Jerry Clarke, US Army Research Laboratory



Swiss National Supercomputing Centre





Renato N. Elias, NACAD/COPPE/UFRJ, Rio de Janerio, Brazil

Supported Data Types

- ParaView Data (.pvd)
- VTK (.vtp, .vtu, .vti, .vts, .vtr)
- VTK Legacy (.vtk)
- VTK Multi Block (.vtm,.vtmb,.vtmg,.vthd,.vthb)
- Partitioned VTK (.pvtu, .pvti, .pvts, .pvtr)
- ADAPT (.nc, .cdf, .elev, .ncd)
- ANALYZE (.img, .hdr)
- ANSYS (.inp)
- AVS UCD (.inp)
- BOV (.bov)
- BYU (.g)
- CCSM MTSD (.nc, .cdf, .elev, .ncd)
- CCSM STSD (.nc, .cdf, .elev, .ncd)
- CEAucd (.ucd, .inp)
- CMAT (.cmat)
- CTRL (.ctrl)
- Chombo (.hdf5, .h5)
- Claw (.claw)
- Comma Separated Values (.csv)
- Cosmology Files (.cosmo, .gadget2)
- Curve2D (.curve, .ultra, .ult, .u)
- DDCMD (.ddcmd)
- Digital Elevation Map (.dem)
- Dyna3D(.dyn)
- EnSight (.case, .sos)
- Enzo boundary and hierarchy
- ExodusII (.g, .e, .exe, .ex2, .ex2v.., etc)
- ExtrudedVol (.exvol)
- FVCOM (MTMD, MTSD, Particle, STSD)
- Facet Polygonal Data
- Flash multiblock files
- Fluent Case Files (.cas)
- GGCM (.3df, .mer)
- GTC (.h5)
- GULP (.trg)
- Gadget (.gadget)
- Gaussian Cube File (.cube)
- JPG Image (.jpg, .jpeg)
- LAMPPS Dump (.dump)
- LAMPPS Structure Files
- LODI (.nc, .cdf, .elev, .ncd)
- LODI Particle (.nc, .cdf, .elev, .ncd)
- LS-DYNA (.k, .lsdyna, .d3plot, d3plot)
- M3DCI (.h5)
- MFIX Unstructred Grid (.RES)
- MM5 (.mm5)
- MPAS NetCDF (.nc)
- Meta Image (.mhd, .mha)
- Miranda (.mir, .raw)
- Multilevel 3d Plasma (.m3d, .h5)
- NASTRAN (.nas, .f06)
- Nek5000 Files
- Nrrd Raw Image (.nrrd, .nhdr)
- OpenFOAM Files (.foam)
- PATRAN (.neu)
- PFLOTRAN (.h5)
- PLOT2D (.p2d)
- PLOT3D (.xyz, .q, .x, .vp3d)
- PLY Polygonal File Format
- PNG Image Files
- POP Ocean Files
- ParaDIS Files
- Phasta Files (.pht)
- Pixie Files (.h5)
- ProSTAR (.cel, .vrt)
- Protein Data Bank (.pdb, .ent, .pdb)
- Raw Image Files
- Raw NRRD image files (.nrrd)
- SAMRAI (.samrai)
- SAR (.SAR, .sar)
- SAS (.sasgeom, .sas, .sasdata)
- SESAME Tables
- SLAC netCDF mesh and mode data
- SLAC netCDF particle data
- Silo (.silo, .pdb)
- Spheral (.spheral, .sv)
- SpyPlot CTH
- Spy Plot (.case)
- Stereo Lithography (.stl)
- TFT Files
- TIFF Image Files
- TSurf Files
- Tecplot ASCII (.tec, .tp)
- Tecplot Binary (.plt)
- Tetrad (.hdf5, .h5)
- UNIC (.h5)
- VASP CHGCA (.CHG)
- VASP OUT (.OUT)
- VASP POSTCAR (.POS)
- VPIC (.vpc)
- VRML (.wrl)
- Velodyne (.vld, .rst)
- VizSchema (.h5, .vsh5)
- Wavefront Polygonal Data (.obj)
- WindBlade (.wind)
- XDMF and hdf5 (.xmf, .xdmf)
- XMol Molecule

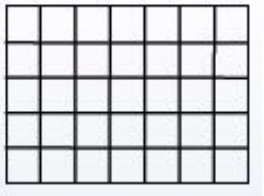
Data Types



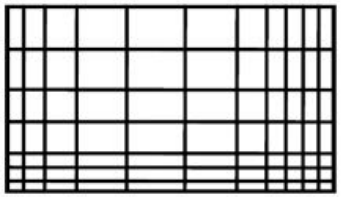

invent, develop, deploy, and deliver

PERVASIVE TECHNOLOGY INSTITUTE

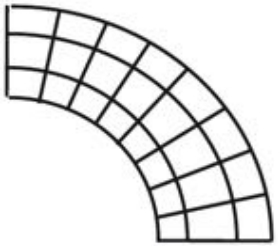
vtkImageData



vtkRectilinearGrid

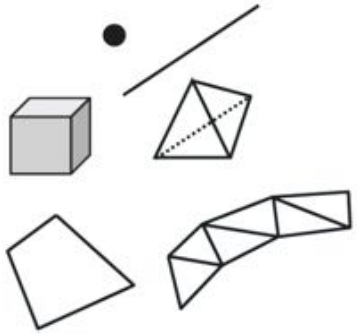


vtkStructuredGrid



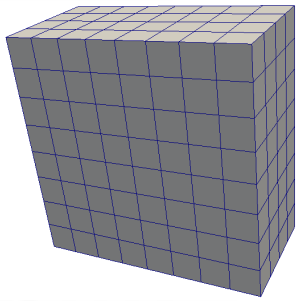
vtkPolyData

vtkUnstructuredGrid

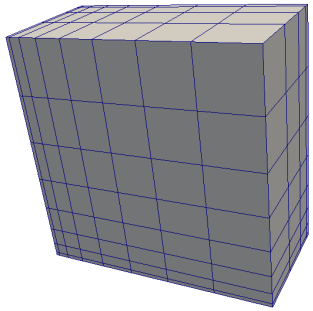


Data Types (not limited to 2D)

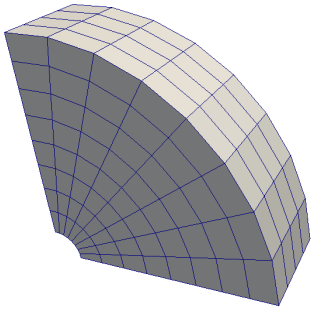
invent, develop, deploy, and deliver
PERVASIVE TECHNOLOGY INSTITUTE



Uniform Rectilinear
(vtkImageData)



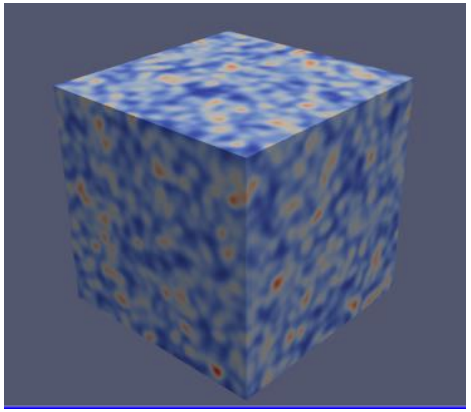
Non-Uniform Rectilinear
(vtkRectilinearGrid)

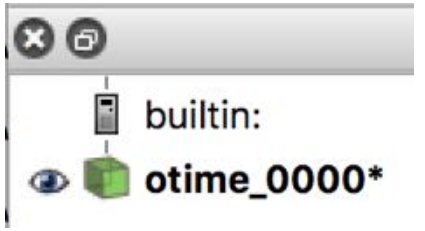


Curvilinear
(vtkStructuredGrid)

Basic approach to data exploration in ParaView

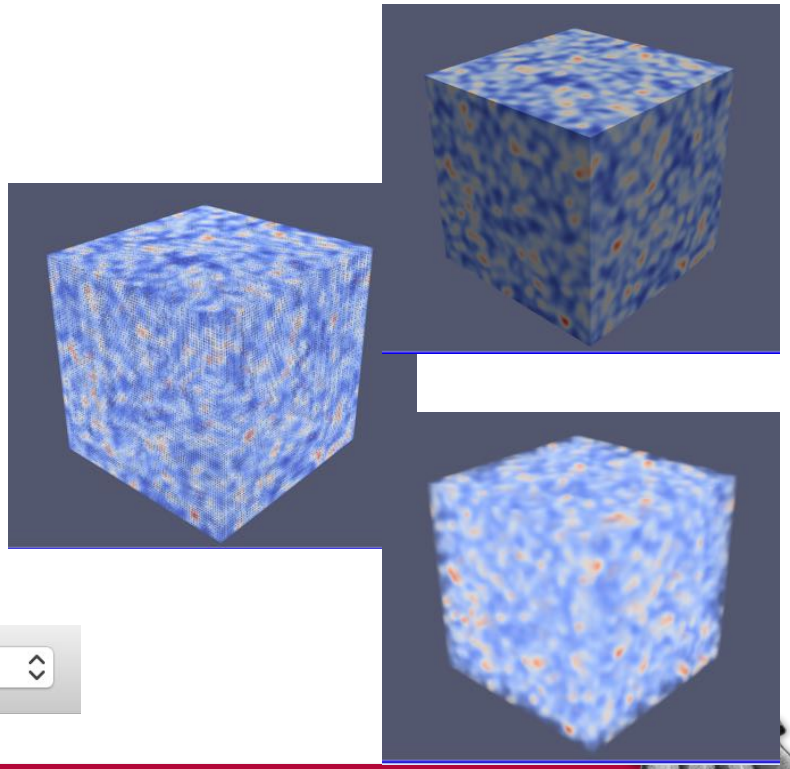
- Horowitz Neutron denstiy data
  - Original data: particle positions
    - Processed using Gaussian Splatting into Volume:
  - Data set: (otime)
    - Volume data
    - Multi-time step





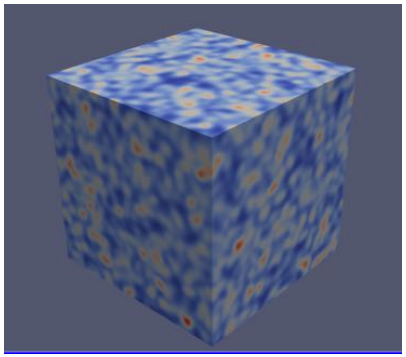
Basic approach to data exploration in ParaView

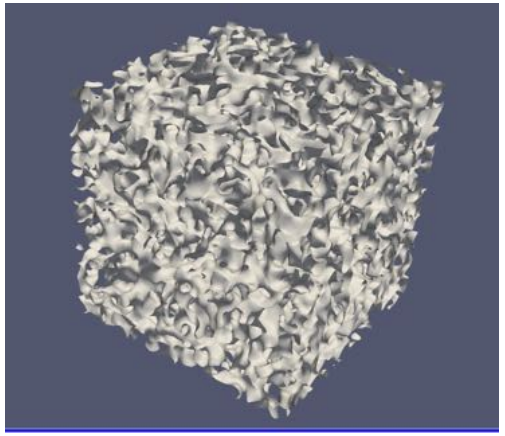
- Basic visualization techniques:
  - Points
    - 3D Glyphs
  - Slice
  - Wireframe
  - Surface
  - Surface w/ Edges
  - Volume
    - → Adjust color maps (opacity)

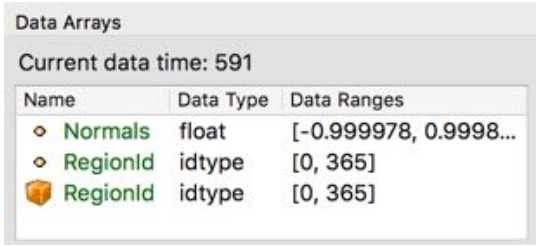


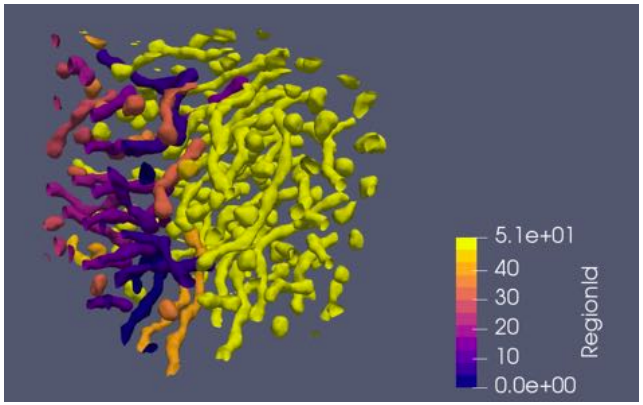
Basic approach to data exploration in ParaView

- Enhancing the visualization
  - Contour Filter (0.035)
  - Connectivity
    - Colors:
      - Discretize to 12
      - Choose a varying colormap
      - Set range to 0-400
    - Play to follow changes over time







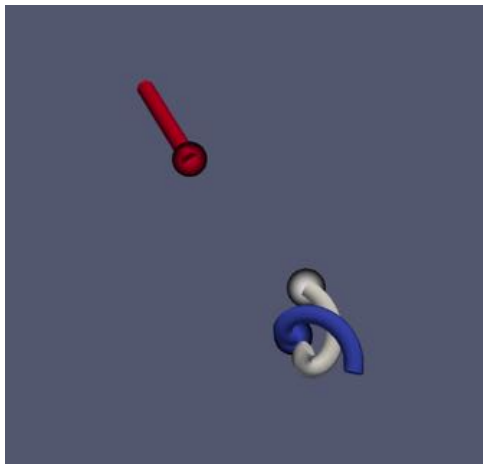


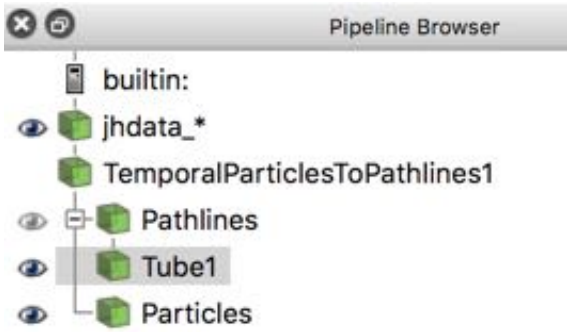
Basic approach to data exploration in ParaView

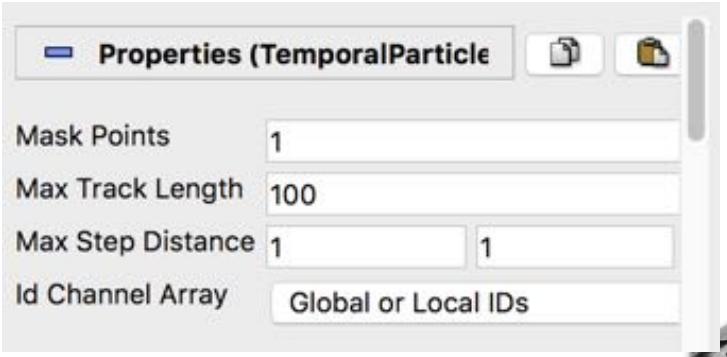
- Vesperini Particle location data
  - Original data
    - Columns of ASCII encoded numbers
    - Output from Starlab N-Body simulation
  - Data set: (jhdata/evdata)
    - Point data
    - Multi-time step
    - JH (Jongsuk Hong data)
      - binary/trinary star collisions

Basic approach to data exploration in ParaView

- Particles in motion
  - Path tracing

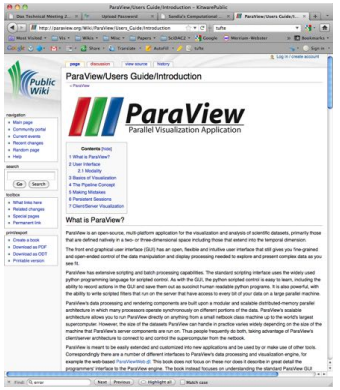




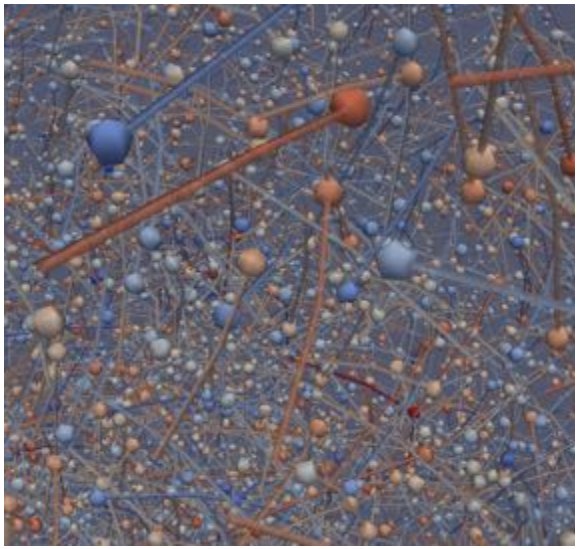


More Information

- Online Help 
- *The ParaView User's Guide*
  - http://paraview.org/Wiki/ParaView/Users_Guide/Table_Of_Contents
- The ParaView web page
  - www.paraview.org
- ParaView mailing list
  - paraview@paraview.org



Questions?



(or perhaps a video)

Thank You!

Discussion

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